

## Article

# Transformation towards Circular Economy (CE) in Municipal Waste Management System: Model Solutions for Poland

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**Abstract:** Municipal waste management has been an area of special interest for the European Commission (EC) for many years, especially in the transformation process towards a circular economy (CE), which is a priority of the European Union's (EU's) economic policy. This paper presents the overview of the Polish waste management system (WMS) and the CE-related tasks indicated in the Polish CE Roadmap. Despite the fact that Poland is one of the countries that generates the least waste per capita (329 kg in 2018) in the EU (489 kg), it still has problems with adapting the levels of municipal waste recycling to European requirements (34.3% in 2018, EU average 47%), which result from the lack of sufficient infrastructure for waste management and the insufficiently developed public awareness and behaviors. The current paper presents an inventory of the recommended actions, which support transformation towards CE in municipal waste management. These actions have been grouped into six core principles of circularity, indicated in the ReSOLVE framework: Regenerate, Share, Optimize, Loop, Virtualize, and Exchange. In each of presented areas, recommended tasks and actions were identified that should be taken by governments and residents themselves, such as landfill remediation, use of selected municipal waste fractions for economic purposes, sharing products with co-users, waste recovery, remanufacturing products or components, virtual solutions in everyday life to reduce the amount of generated waste, or replacement of household appliances by items with a higher energy class. An implementation of specific actions indicated in the paper could positively influence transformation towards CE in Poland. Because the presented examples of actions are model solutions, they can also be used in other countries and regions.

**Keywords:** waste management; waste; municipal waste; circular economy (CE)

## 1. Introduction

Municipal waste management is an important area of the European Commission's (EC's) interest and a significant element of the plan for transformation towards a circular economy (CE) in the European Union (EU). The EC clearly expresses its position on municipal waste management in the key CE-related communications and official documents, published in the previous years:

- First: "Communication towards a circular economy: A zero waste program for Europe" [1]: Action must be taken in order to increase the reuse and recycling of municipal waste, to strive to eliminate landfills, to prohibit the storage of recyclable plastics, metals, glass, paper, and cardboard as well as biodegradable waste, to support the development of markets for high-quality secondary raw materials, to clarify the calculation method for recycled materials, and to change consumer behavior in the area of the circular economy;

- Second: “Communication on closing the loop: An EU action plan for the Circular Economy” [2]: Identified 54 activities, including municipal waste management and a part containing proposals for legislative changes regarding waste;
- Third: “Communication on a monitoring framework for the Circular Economy” [3]: Ten key CE indicators covering each stage of the product life cycle and competitiveness aspects, including indicators related to municipal waste;
- Fourth: “Communication on a new Circular Economy Action Plan for a cleaner and more competitive Europe” [4], where the EC underlined that, despite efforts at the EU and national level, the amount of waste generated is not going down, and further considerable efforts focused on sustainable waste management are required.

Moreover, in 2018, the EC presented the amended content of the Waste Framework Directive, setting ambitious targets for increasing the reuse and recycling of municipal waste to a minimum of 65% by 2035 [5]. In the face of the increasing amount of municipal waste generated in European countries in recent years, which is the result of the intensification of consumption, it has become very important to look for sustainable methods of its management [6,7]. To this end, it is necessary to navigate in accordance with the European waste hierarchy [8], the overarching goal of which is to prevent its generation and reduce quantities [9], followed by recycling and other forms of disposal, incineration (with the energy recovery), and safe storage [10]. At the same time, there are clear differences regarding the amount and composition of waste generated [11], as well as methods of its management in individual countries [12,13] and regions, resulting from many socio-economic and technical factors, including the wealth level of the society as well as the development [14] and application of modern recycling and disposal installations [15]. Due to the fact that the main challenge in waste management for the coming years is the transition to the CE model [16], undoubtedly, it is necessary to monitor both changes in the management of municipal waste in individual Member States and their effects [17]. This seems even more important because, in 2018, the EC indicated waste management as one of the elements of the framework for monitoring the transformation process towards the circular economy. The monitoring framework presents 10 CE indicators, among which issues related to municipal waste appear directly in two areas of CE—in waste management (e.g., municipal waste recycling rate) and in the production area (municipal waste generation rate per capita) [3]. It should also be pointed out that the EC recommended the Member States to develop the CE implementation plans (roadmaps) on the national level. Selected European countries have already developed and officially adopted the CE roadmaps, such as Germany, Finland, or Poland. The national CE plans are currently available on the website of the European Circular Economy Stakeholders Platform [18], and the summaries of the adopted approaches in the selected countries have been studied and presented by the European Environmental Agency in a report [19]. In each of the published national CE action plans, the importance of municipal waste management (or selected streams of municipal wastes) is stressed, with emphasis on the implementation of the principles of sustainability [20] and circular economy [4] in the everyday life of residents, but also in the area of responsibility of governments for taking action in the field of better management of municipal waste.

In Poland, in 2016, the Ministry of Development started work on the Roadmap “Transformation towards a circular economy”, which was adopted by resolution of the Council of Ministers in September 2019. Pursuant to the ordinance of the Minister of Development, in June 2016, a Circular Economy Working Group (CE Working Group) was appointed, to which representatives of the following departments were invited: Environment, energy, infrastructure and construction, national education, science and higher education, family, work and social policy, agriculture and rural development, and health, as well as entrepreneurs, science representatives, and other entities involved in the development of circular economy in Poland [21]. Since 2014, Poland has started its activities related to the circular economy in various areas of economic activity [22], including municipal waste management. It should be pointed out that the Polish CE Roadmap is based on the CE outline commonly used at the European level, which has been developed by the Ellen MacArthur Foundation [23]. The CE outline assumes the

existence of two cycles: Biological, with emphasis on renewable raw materials, and technical, focused on non-renewable raw materials. The main principle of both cycles is optimization of resource yields by circulating products, materials, and components at the highest utility at all times.

Implementing CE assumptions in national economies requires a model approach [24,25], and this also refers to municipal waste management systems. The Polish CE Roadmap provides the key elements and directions of transformation towards CE in municipal waste management, but no model solutions were identified that could accelerate the transformation process. At the same time, the Polish Roadmap indicates that the ReSOLVE framework, which includes six actions—Regenerate, Share, Optimize, Loop, Virtualize, and Exchange [23]—can be used as a tool for deepening the implementation of circular economy in various areas of the economy. The ReSOLVE framework was developed by the Ellen MacArthur Foundation and McKinsey, which are important bodies in the development of tools supporting the process of transformation towards CE in the EU. The current study presents an inventory of recommended actions for improving the Polish municipal waste management system, which have been grouped into the core areas indicated in the ReSOLVE framework. The proposed solutions can also be used in other municipal waste management systems as the recommended directions in the process of the transformation towards CE in Europe. The structure of this paper is as follows:

- Clarification of the subject of the study (introduction);
- Research framework—methods used in the paper;
- Overview of circular economy principles in municipal waste management in the EU;
- Overview of the Polish system of municipal waste management, including CE aspects;
- Inventory of the CE actions for municipal waste management;
- Discussion and conclusions.

## 2. Research Framework

The research focuses on the presentation of the possible ways of CE's implementation in municipal waste management in Poland. The structure of the study includes a comprehensive literature review on the CE approach in municipal waste management at the European level and a review of the waste management system in Poland, including the actions taken by the Polish government in order to transform the municipal waste management system into the CE model. Moreover, an inventory of the actions towards the CE model in municipal waste management systems is presented based on the ReSOLVE framework. The assumed research framework is presented in Figure 1, and a description of the methods used in this paper is presented below.

Step 1: A comprehensive literature review, which includes the detailed description of municipal waste management in Poland, was done with the use of the desk research method. The analysis was done based on an overview of the European and national law restrictions (EUR-lex), the European and national CE-related documents, and the available reviewed papers (Elsevier Scopus, Elsevier ScienceDirect, Google Scholar). All of these items were selected with the use of a few keywords: "Circular economy", "CE", "CE indicators", "CE monitoring", "waste management", "municipal waste", "waste", "zero waste", and "recycling". Important sources of data include the European CE communications and directives, the Polish CE Roadmap, EU statistics reports and Polish statistical reports. The results of the European CE indicators in Poland (based on the CE Monitoring Framework of the EU) related to municipal waste were presented for two indicators (municipal waste production per capita in the area of production and consumption, as well as municipal waste recycling in the area of waste management). For this purpose, statistical data on municipal waste in Poland, published by the Eurostat, were used. Data have been presented since 2014, i.e., since the initiation of the need to switch to the CE model in the EU [1].

Step 2: Identification and inventory of the set of actions supporting the transformation towards the CE model in municipal waste management were done with the use of the method of synthesis (combining distinguished factors), induction (deriving conclusions from the premises that are their

individual cases), and group discussion (consultation in the group of authors and with external experts). The model solutions were proposed for all areas of circularity, as identified in the ReSOLVE framework: Regenerate, Share, Optimize, Loop, Virtualize, and Exchange [23]. In each of the presented areas, the specific tasks were proposed, and recommendations on how to implement the CE assumptions in municipal waste management were provided. The basic description of the selected elements of the ReSOLVE framework is provided in Section 5.1, and detailed characteristics of the selected actions are presented in the supplementary materials.



**Figure 1.** The assumed research framework in the current study.

### 3. Municipal Waste Management in the Circular Economy (CE)

Municipal waste management is a part of the transition to the CE model in the EU [1–4]. The first CE document published by the EC was the vision of the “zero waste program” for Europe [1]. This communication is a key document in the implementation of the CE model in the EU because it clearly outlines the steps to be taken to move from a linear economy to a circular economy. The vision of the EC was an elimination of municipal waste landfilling. Moreover, it was shown that positive changes in municipal waste management can boost the economic, environmental, and social benefits in the EU’s countries. In 2015, the second document on CE was published, the so-called CE Action Plan or CE Package. The CE Action Plan included the propositions of long-term actions to reduce landfilling of waste (including illegal landfill sites) and to increase its preparation for reuse and recycling [26,27]. The EC indicated here that the key waste streams are municipal waste and packaging waste. The CE Package also included a second part, i.e., proposal to revise the most important EU waste legal documents, such as the Waste Framework Directive (WFD) [28], Landfill Directive [29], Packaging Directive [30], Directives on End-of-Life Vehicles, Batteries, and Accumulators [31] and Directive on Waste Electrical and Electronic Equipment (WEEE) [32]. Moreover, the eco-design directive is an important document related to energy-related items that can be converted to municipal waste [33]; it is the basis for sustainable product design. In 2018, the new Directive on Waste [5] was implemented, which was amending the Directive [28]. Despite the fact that municipal waste represents only approximately 10% of the total waste produced in the EU (measured by weight), this waste stream is amongst the most complicated and complex ones to manage [34]. The EC underlined that countries that adopted efficient municipal waste management systems show better performance in

overall waste management [35]. In January 2018, the EC presented the framework for monitoring the circular economy [3], stressing that it is not possible to indicate one universally recognized closed-loop indicator due to the complexity and numerous dimensions of the transition to the CE in various areas of the economy. For this reason, for the needs of the monitoring framework, a set of relevant indicators was proposed, grouped into four main areas of the CE: Production and consumption, secondary raw materials, waste management, and competitiveness and innovation. Among 10 CE indicators, special attention is devoted to municipal waste because many of these indicators are directly related to municipal waste generation and management, as is indicated in Table 1.

**Table 1.** Characteristics of the selected indicators related to municipal waste management in the European Union (EU) [3,36].

CE Indicator	Definition	Average Value for the EU
<b>Production and consumption</b>		
Municipal waste production per capita	Indicates the amount of the waste collected by or on behalf of municipal authorities and disposed of through the waste management system	489 kg/capita (in 2018)
Food waste production	Indicates the amount of the waste generated in the production, distribution, and consumption of food	reached 80 Mg (in 2016)
<b>Waste management</b>		
Overall municipal waste recycling indicator	Includes the share of recycled municipal waste in the total amount of municipal waste generated. The recycling is related to material recycling, composting, and anaerobic digestion	47% (in 2018)
Overall packaging waste recycling rate	Includes the share of recycled packaging waste in all packaging waste generated, i.e., wasted material that was used for the protection, containment, delivering, handling, and presentation of goods, from raw materials to processed goods, from the producer to the user (consumer), excluding production residues	67% (in 2017)
Recycling indicator for waste electrical and electronic equipment	Is calculated by multiplying the “collection rate” as set out in the Waste Electrical and Electronic Equipment (WEEE) Directive with the “reuse and recycling rate” set out in the WEEE Directive [28]	41.4% (in 2016)
Bio-waste recycling	It presents the ratio of composted/methanized municipal waste over the total population	83% (in 2018)

The European CE indicators are regularly updated and made available on the European Statistical Office’s website—Eurostat [37]. Moreover, detailed information for the presented CE indicators is provided for the selected European countries, and can be found on the EC webpage [38]. The site also includes tools to monitor progress and documents methods for indicators, data sources, definitions, and publication standards. However, the existing tools for monitoring are inadequate for tracking the progress of CE transition at the regional level [24]. From the point of view of municipal waste management, monitoring of identified CE indicators at the regional level is recommended [39].

The EC also underlined in the new CE Action Plan that, in the following years, new indicators will be proposed, particularly in areas of the CE, especially those concerning waste from the agri-food sector and green public procurement (GPP) [4]. There are more CE indicators proposed by researchers, which are also useful to support CE progress in the EU [40,41]. The EC also provided the specific objectives in the Waste Framework Directive [5] in the area of municipal waste management in order to implement the CE model in Europe: Reuse and recycling of municipal waste by up to 55% by 2025, 60% by 2030, and 65% by 2035. Moreover, in order to create the European recycling society (with a high level of resource efficiency), the EU’s countries should increase the preparation for reuse and recycling of municipal waste in order to deliver substantial economic, environmental, and social



benefits and to accelerate the shift towards the circular economy [5]. It should be emphasized that the Commission continues its activities in the field of municipal waste; in the new CE Action Plan adopted in 2020 [4], municipal waste management is indicated as an important target of the EU, and the legislative proposals on waste, adopted together with the action plan, propose long-term targets to reduce landfilling and to increase preparation for reuse and recycling of key waste streams, such as municipal waste and packaging waste.

#### 4. Municipal Waste Management in Poland

The municipal waste management system in Poland has changed a lot in recent years as a consequence of adaptation to EU requirements, both in the scope of implementing the waste directive [5] and the ambitious CE package from 2015 [2]. Through gradual and consistent introduction of the changes and many amendments to Polish legislations [42], the municipal waste management system transformed into an individual economy branch focused on protection of the environment [43]. This section provides the most important information about the changes in structure of municipal waste management in Poland and the directions of CE implementation indicated by the Polish government.

##### 4.1. Basic Principles of the Polish Municipal Waste Management System

Waste management in Poland is realized based on the European waste management hierarchy [28], in which waste prevention and preparation for reuse are the most desirable scenarios, followed by recycling (including composting) and other recovery methods (e.g., incineration with energy recovery—a solution that raises conflicting opinions in some countries). The last element in the hierarchy is the removal (disposal) through storage of waste that cannot be subjected to recovery or disposal processes that is safe for human health and the environment. Although this option is the most harmful to the environment and health, it is one of the cheapest methods of waste management. It should be emphasized that this hierarchy determines the order of actions taken in waste management, which is particularly important when it is assumed that this hierarchy creates a certain sequence of actions regulated by law.

In Polish legislation, currently applicable regulations in the field of municipal waste management are specified in:

- Act of 14 December 2012 on waste [44],
- Act of 25 January 2013 amending the act on maintaining cleanliness and order [45],
- Act of 23 January 2020 amending the act on waste and certain other acts [46].

Act of 14 December 2012 on waste came into force on 23 January 2013, and it is an implementation of Community law—the Waste Directive of 2008 [28]. This Act sets out measures to protect the environment and the lives and health of people, preventing and reducing negative impacts on environment and human health resulting from the generation and management of waste, and limiting the overall effects of resource use and improving the efficiency of such use. Pursuant to the Act on waste [44], the principles of waste management should pursue the following objectives:

- Maximum reduction of waste during all business activities and people's lives,
- Immediate integration of production residues back into production,
- Recovery of raw materials from collected waste,
- Use of waste treatment processes,
- Waste storage in an orderly manner with minimal impact on the environment [47].

The implementation of the mentioned Act on waste in 2013 was a fundamental change in order to impose on municipalities an obligation to prepare local systems for collection of municipal waste from owners of inhabited real properties, with the possibility of extending this system to other real properties where municipal waste is generated in exchange for a fee paid by property owners [48]. Therefore, currently, municipal waste management is a part of actions realized by the municipalities,

and entrepreneurs are obliged to participate in tenders for collection and management of municipal waste. The obligations of municipalities in terms of collection and management of municipal waste consist of:

- “Covering inhabited real properties and, optionally, other real properties with the municipal system,
- Adopting appropriate acts of local law,
- Managing resources from the fees charged to property owners,
- Introducing selective collection of waste,
- Ensuring the functioning of the municipal waste selective collection center (MWSCC),
- Achieving levels of recycling, preparing for reuse and recovery of certain fractions of municipal waste, and reducing the weight of biodegradable municipal waste to be landfilled,
- Ensuring the functioning of the regional installation for municipal waste treatment (RIMWT),
- Carrying out information and education measures in the field of proper handling of municipal waste,
- Supervising municipal waste management, inter alia, by controlling a stream of municipal waste generated in the municipality and operators collecting municipal waste,
- Carrying out an annual analysis of the state of municipal waste management in order to verify the technical and organizational possibilities of the municipality as regards municipal waste management” [48].

In order to improve the Polish waste collection and management system, to comply with EU regulations, and to harmonize the municipal waste segregation system throughout the country, in 2019, new rules on waste segregation were introduced in Poland. The municipal waste should be selectively segregated by residents of the country. The new municipal waste collection system has five fractions (previously three), which residents should separate:

- Paper—blue,
- Glass—green,
- Metals and plastics—yellow,
- Bio-waste—brown,
- Mixed waste—black.

It is worth mention that all Member States are obliged to develop National Waste Prevention Plans (NWMP). In Poland, the plan currently in force was adopted in 2016, with the perspective of being implemented up to 2022 [48]. This document was drawn up according to the requirements set out in the Act of 14 December 2012 on waste [44]. The first mentioned waste stream indicated in the framework of the NWMP 2022 is municipal waste (including food waste and other biodegradable waste). Moreover, each voivodship (the highest-level administrative subdivision of Poland; currently, there are 16 voivodships) prepared its regional waste management plan, in which municipal waste is a key issue.

In January 2020 [46], the new system of waste registration, the so-called Waste Database (Polish—Baza Danych o Odadach—BDO) was introduced in Poland, which is a register of entities introducing products, packaged products, and waste management. The register is kept in electronic form. According to the authors of legislative changes, it is to help control waste management, prevent illegal waste disposal, enable electronic fulfillment of registration, and reporting obligations. It should be underlined that the Waste Database is an obligatory tool of waste evidence for companies that generate non-municipal waste.

#### *4.2. Circular Economy Assumptions in the Polish Municipal Waste Management System*

The Polish Roadmap “Transformation toward Circular Economy” was adopted by the government in September 2019 [49]. The Polish CE Roadmap is the result of the CE Working Group established in

2016 by the Ministry of Development. Representatives of the companies, ministries, research, education, and individuals involved in the development of circular economy in Poland have been invited to the CE Working Group, including the authors of this article. Preparation of this document was necessary because the depletion of raw materials [22], the increase in their prices, and growing dependence on suppliers from third countries [50] pose a serious threat to the further economic development of Poland and a challenge in the context of environmental protection. The Polish government recognized that the implementation of the CE assumptions would increase the innovation of Polish entrepreneurs and increase their competitiveness in relation to entities from other parts of Europe and the world. This document contains a set of legislative and non-legislative tools which, after implementation by the Polish administration, should contribute to the introduction of the CE model in Poland. It should be stressed that the Polish Roadmap indicates activities that primarily contribute to reduction of waste generation. The following areas of activity are defined:

- Sustainable industrial production—indication of the important role of industry in the Polish economy and new opportunities for its development;
- Sustainable consumption—showing how big changes are possible at this often overlooked stage of the product's life cycle (e.g., the consumers could buy fewer goods and make better use of what they already have);
- Bioeconomy—it concerns the management of renewable raw materials, which has unique potential in Polish realities;
- New business models—these are possible directions for the reorganization of entrepreneurs so that their activities aim at “closing the loop”;
- Implementation, monitoring, and financing of the circular economy.

The CE Roadmap presents analyses and recommended directions that can be used as a basis to propose legislative changes to increase the use of secondary raw materials in the economy. Moreover, it also includes the proposals for actions of the Polish government in the field of CE implementation in the sector of municipal waste management. They are summarized and presented in Table 2. They have been classified in the area of sustainable consumption and include actions such as the analysis of the effectiveness of current regulations regarding municipal waste, identifying barriers at the local government level in increasing the efficiency of municipal waste collection and management, and analysis of the introduction of alternative methods of municipal waste collection. The proposed actions should be taken by the Ministry of Environment with the support of other Polish ministries. The results of the proposed analyses and recommended directions should be used as a basis to propose legislative changes to increase the use of secondary raw materials in the economy.

The Polish Roadmap underlines that innovative technologies for waste disposal could play a key role in the transformation towards circular economy. Therefore, the Ministry of Development initiated the creation of the National Intelligent Specialization (Polish—Krajowa Inteligentna Specjalizacja—KIS) in the circular economy. In the end of 2019, the “KIS 7: Circular economy—water, fossil raw materials, waste” was established. This indicates the preferential areas of support for research, development, and innovation (R&D&I) in the process of transformation of the Polish economy to the CE model. It is expected that there will be technological developments, especially in the field of clean technologies for waste management, including that of municipal waste.



**Table 2.** Proposals for actions—circular economy (CE) implementation in the area of the sustainable consumption [49].

No.	Proposition of Actions	Relevance	Responsible Body
<b>Municipal waste management</b>			
1	Analysis of the effectiveness of current regulations regarding municipal waste	Analysis of the effectiveness of the current system will be made through the prism of those raw materials derived from municipal waste, which are important raw materials for industry in Poland.	Ministry of Environment
2	Identifying barriers at the local government level in increasing the efficiency of municipal waste collection and management	Analysis will be made at the local level regarding those elements that constitute barriers to increasing levels of municipal waste collection and recycling. Such an assessment should cover both consumers and entrepreneurs, as well as waste management bodies from the local level.	Ministry of Environment
3	Analysis of the introduction of alternative—to existing—methods of municipal waste collection	Analysis of the possibilities of creating additional or complementary existing municipal waste collection systems will be carried out, which—due to specific conditions—could increase the amount of good quality recyclable materials.	Ministry of Environment
<b>Preventing food waste</b>			
1	Dissemination of knowledge among consumers on the prevention of food waste	Systematic educational campaigns aimed at raising awareness among consumers and representatives of the food industry about food waste, among others, are desirable. By disseminating the 4P principle, i.e., planning ahead shopping, processing food to extend its shelf life, storing products in appropriate conditions, and sharing unnecessary food with those in need.	Ministry of Agriculture and Rural Development in cooperation with the Ministry of the Environment
2	Implementation of distribution mechanisms and appropriate handling of products with an end-of-life date	Many collected products (e.g., by charities) cannot be transferred to those in need due to restrictive regulations regarding the expiry dates of products—this leads to certain conditions of wasting nutritious food that could be used and handed over to the needy.	Ministry of Development in cooperation with the Ministry of Agriculture and Rural Development
3	Implementation of incentives for entrepreneurs engaged in counteracting food waste	Considering the economic, environmental, and social dimensions of actions to reduce food losses, it is desirable to introduce mechanisms through which enterprises will be more actively involved in cooperation with charitable organizations dealing with providing food for the needy.	Ministry of Development in cooperation with the Ministry of Agriculture and Rural Development
4	Conducting periodic statistical surveys regarding the scale, structure, and directions of processes related to food waste in Poland	Despite the estimates made by various organizations (both public and private), there is still no full knowledge about the causes and scale of food waste in Poland. Therefore, it is postulated to introduce periodical surveys based on a uniform methodology into official statistics, thanks to which it will be possible to monitor this phenomenon in Poland	Ministry of Agriculture and Rural Development

Table 2. Cont.

No.	Proposition of Actions	Relevance	Responsible Body
<b>Education</b>			
1	Creation of an internet platform	The platform will allow the exchange of information between government administration, business, and local government. The platform should contain user guides in the context of circular economy, information on incentives for entrepreneurs, current support programs, and educational brochures.	Ministry of Development in cooperation with the Ministry of Finance
2	Promotion of sustainable consumption patterns in the education of children and adolescents	Educational activities will be carried out to make informed consumer decisions. These are about: The ability to read and recognize labels and markings on products, the ability to critically analyze advertising messages, the ability to search for information on the impact of consumption on the environment, and the knowledge of the rights and obligations of consumers. Appropriate selection of educational programs will translate into an increase in the ecological awareness of children and adolescents, which will allow them to develop appropriate habits and behaviors in adult life.	Ministry of National Education
3	Incorporation into general curricula of subjects related to rational resource management, clean technologies, energy efficiency, green jobs, and corporate social responsibility	The transition to a circular economy requires significant changes in selected areas of the economy. Dissemination of knowledge on this subject among students and young people will contribute to increasing their level of knowledge, as well as that of the families in which they live. It should also translate into the acceptance of society of the implementation of necessary actions.	Ministry of National Education
4	Promoting knowledge about the circular economy and the principles of dealing with resources within higher education	Introduction to curricula of knowledge about the product life cycle and obtaining raw materials from available new sources, i.e., renewable resources and waste, eco-design principles, etc.	Ministry of Science and Higher Education
5	Social campaign on sustainable consumption patterns	The purpose of the campaign is to disseminate sustainable consumption patterns among all social groups	Ministry of Environment
6	Dissemination of knowledge about the circular economy in municipalities	Implementation of a pilot program addressed to municipalities, which aims to develop good practices in the field of circular economy	Ministry of Environment

The amount of waste produced at the European and global level increases year by year. In Poland, a significant increase can also be observed, and, thus, an increase in the amount of municipal waste generated per capita. In 2018, the average amount of municipal waste generated per capita in Poland was one of the lowest in the EU and amounted to 329 kg per capita, compared to the European average of 489 kg per capita. Changes in the amounts of municipal waste generation in Poland and the EU average in the years 2014–2018 are presented in Figure 2. The further increase in the amount of municipal waste is expected in both Poland and other European countries as the consequence of increasing urbanization, a rising standard of living, and changing patterns of social habits and behavior that are mainly related to the higher consumption [51]. Areas with a large numbers of tourists per year are exposed to the production of municipal waste by visitors [52,53]; in Poland, they are mainly large cities with well-preserved historical cities [54], such as Cracow, Poznan, or Gdansk [55,56].

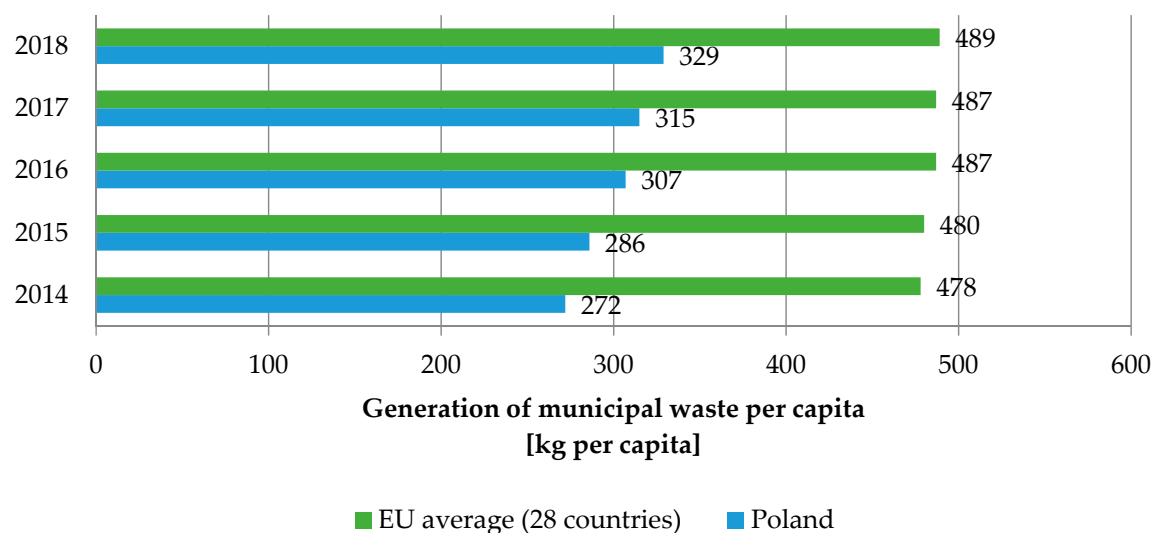
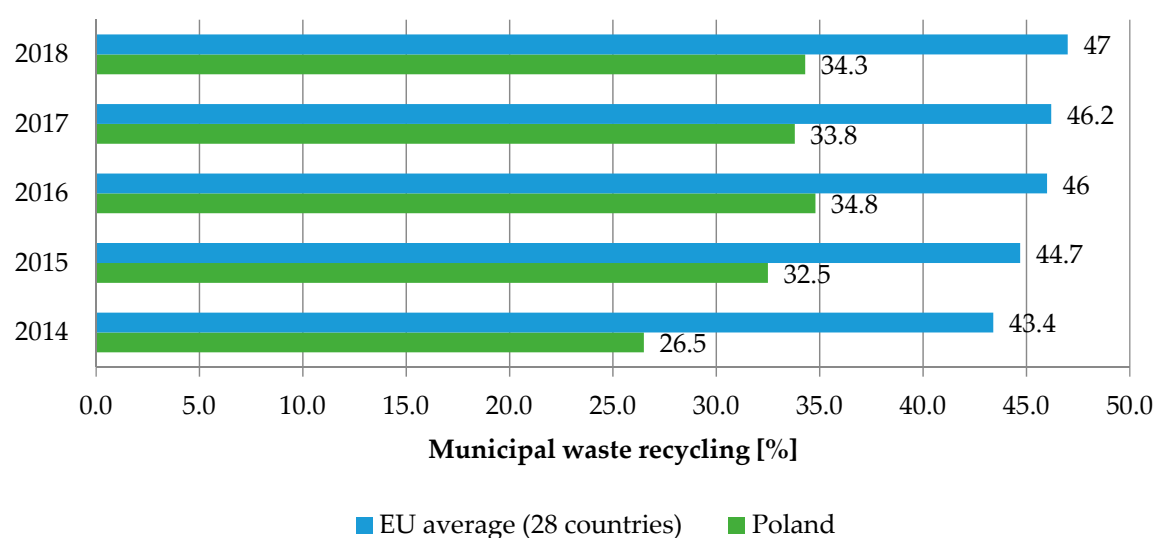


Figure 2. Municipal waste generated in Poland and the EU in 2014–2018 [37].

Despite generating less municipal waste than the EU average, Poland faces still problems related to the insufficient levels of municipal waste collection and disposal [57], which deviate from the highest European and world levels. This creates serious problems, from both the environmental and economic points of view. Of the municipal waste generated in 2017 in Poland, about 93% was mixed waste and 27% collected waste selectively. Municipal waste fractions collected or collected selectively per capita included (in 2018): Biodegradable waste (26.4 kg per capita), glass waste (13.1 kg per capita), bulky waste (13.7 kg per capita), plastic (8.6 kg per capita), paper and cardboard (7.0 kg per capita), and mixed packaging waste (15 kg per capita) [58]. There is a positive trend in the selective waste collection, and, in 2018, it reached 28.9% of the total amount of municipal waste generated. However, these data are still not satisfactory, and residents should be more encouraged to separate waste collection. Moreover, a variable amount of waste collected selectively in individual regions is observed, which is a result of a different systems of collecting this type of waste, which are organized by local authorities. In 2017, three municipalities obtained over 90% all collected waste was collected selectively, while nine municipalities selectively collected less than 1% of waste [16]. The further actions focused on an effective selective waste collection system and measurement of its effectiveness with the use of, e.g., the Selective Collection Quality Index [59]; this is indicated as a fundamental strategy of municipal waste management in Poland [60].

Moreover, there is still an insufficient supply of recyclable materials for the domestic economy. The reconstruction of the municipal waste management system introduced in 2012–2013 did not lead to significant changes in the waste disposal structure. Creating an economy that fully implements the CE approach requires the use of as much municipal waste as possible through recycling. This, in turn, requires that the waste is collected selectively and that it is of good quality. From the perspective of

CE implementation, municipal waste recycling is one of the most important CE indicators provided in the CE monitoring framework [3]. Changes in the value of this indicator in Poland and the EU average in the years 2014–2018 are presented in Figure 3. The level of waste recycling in Poland has been increasing in recent years, from 26.5% in 2014 to 34.3% in 2018. The European average is also rising, at a lower speed, from 43.4% in 2014 to 47% in 2018. The countries with the lowest recycling rates (in 2017) are Malta (6.4%), Romania (13.9%), Cyprus (16.1%), and Greece (18.9%). Germany has been the leader in the field of municipal waste recycling for many years, and, in 2017, it recycled 67.6% of generated municipal waste. High levels of recycling were also achieved in Belgium (53.7%), the Netherlands (54.2%), Austria (57.7%), Slovenia (57.8%), and Switzerland (52.5%) [37]. In Poland, recycling of municipal waste is below the European average, and this deviation from the European average indicates a large potential for improvement [61]. The low rates of municipal waste recycling in Poland compared to the European average are a consequence of the lack of sufficiently developed infrastructure for waste processing, efficient functioning like that in developed countries, such as Germany or Denmark, and lower public awareness of the issue of municipal waste [62]. It can be assumed that Poland faces significant challenges in obtaining the recycling rates demonstrated in the new waste directive [5], which assume reuse and recycling of municipal waste by up to 65% in 2035. It should be underlined that, in order to increase the demand and the value of recycled materials, improving the quality of the collected materials is necessary [63].



**Figure 3.** Recycling of municipal waste in Poland and the EU in 2014–2018 [37].

An important aspect in the area of sustainable consumption in the Polish CE Roadmap is prevention of food waste. Food waste has been growing in importance in the previous years due because 9 million Mg of food are wasted annually in Poland. This process occurs at all stages—production, distribution, and consumption. Production is responsible for wasting nearly 6.6 million Mg (73%) of food waste, households waste over 2 million Mg (22%), and other sources waste 0.35 million Mg (4%). In previous years, the above data placed Poland in the fifth position of countries wasting food (% of food wasted) in the European Union—after Great Britain, Germany, France, and the Netherlands [49]. It was indicated that, in other countries, the scale of food waste is greater among consumers, while in Poland, the food industry is the main source of food waste. The EC plans to reduce the amount of food waste by 2030. To achieve this goal, the EC is working on a common EU methodology for measuring food waste and identifying relevant indicators, taking action to clarify EU food waste legislation, and exploring ways to improve product expiry date labeling. In the Polish CE Roadmap, there are several actions that can help reduce the amount of wasted food (Table 2), such as the dissemination of knowledge among consumers on the prevention of food waste, implementation of distribution mechanisms and appropriate handling of products with an end-of-life date, implementation of

incentives for entrepreneurs engaged in counteracting food waste, and conducting periodic statistical surveys regarding the scale, structure, and directions of processes related to food waste in Poland. The responsible bodies for these actions are the Ministry of Agriculture and Rural Development in cooperation with the Ministry of the Environment and the Ministry of Development. Reducing food waste requires changes in consumer habits. Therefore, the third important aspect in the area of the sustainable consumption is the education of consumers, as well as implementation of positive changes in their awareness, behaviors, trends, and attitudes. They should also be open to changes related to the implementation of pro-environmental solutions in everyday life because, without the conscious involvement of consumers, it is impossible to achieve success in the area of sustainable consumption. One of the most important areas where the consumer could accelerate the implementation of the CE is the proper collection and management of municipal waste, which, despite the fact that they represent a small percentage of waste generated in Poland (up to 10% of total waste), they have the greatest impact on awareness, and this directly translates into the quality of life of residents. Therefore, in the Polish CE Roadmap, raising consumers' awareness, strengthening their rights regarding access to product and producer information, and ensuring the safety of the products offered have been indicated as the important issues. It was underlined that sustainable consumption, education at all stages of formal education and training, and non-formal and informal learning from the pre-school level can play a key role. Education is to help shape consumer attitudes and gain experience to develop optimal market behavior patterns. Consumer behavior at the stage of selecting products and services may be of key importance for implementing the CE. The specific recommendations include incorporation into general curricula of subjects related to rational resource management, clean technologies, energy efficiency, green jobs and corporate social responsibility, promoting knowledge about the CE and the principles of dealing with resources within higher education, development of the social campaign on sustainable consumption patterns, and dissemination of knowledge about the CE in municipalities. The actions related to education should be taken through the collaboration of several Polish ministries, such as the Ministry of Development, the Ministry of Finance, the Ministry of National Education, the Ministry of Science and Higher Education, and the Ministry of Environment. It is also worth mentioning that the studies on ecological awareness indicate that Poles are aware of the threats arising from excessive use of resource production [49]. Nevertheless, they do not know practical ways to prevent this phenomenon [64]. In previous years, actions taken by one of the Polish cities have proven that an educational campaign based on home advisors (which were selected from local schools and trained on sustainable waste management principles) visiting as many households as possible can bring satisfactory results. Informing residents about the local waste segregation system, supported by a short survey about residential attitudes and behavior, and further distribution of appropriate educational materials resulted in an increase in recycled municipal waste collected in Jasło City. This educational campaign also impacted positively upon the students' (which played the roles of home advisors) knowledge about waste issues, and provided opportunities for students' relatives and the whole local community to be more environmentally conscious through the process of intergenerational communication and influence [65].

Based on the state-of-the-art analysis, it was possible to indicate that various activities are being undertaken in the field of transformation towards CE that can be treated as model solutions, but no structured implementation areas for them are provided. One of the possibilities is the use of existing tools to structure the recommended activities. In the current paper, the model solutions have been assigned to specific areas of importance indicated in the ReSOLVE framework, which is the EC-recommended model for the CE's implementation.

## 5. Results

Implementation of the circular economy assumptions in national economies requires a model approach, and this also applies to municipal waste management systems. Therefore, the current section provides examples of possible model solutions for the implementation of the CE assumptions



in the municipal waste management systems. This chapter presents the specific solutions proposed for municipal waste management in Poland, including the circular economy assumptions and perspectives of possible application of proposed actions to the Polish conditions.

### *5.1. Recommended CE Actions in Municipal Waste Management*

The presented CE model solutions have been grouped into the six groups (Regenerate, Share, Optimize, Loop, Virtualize, and Exchange) indicated in the ReSOLVE framework [23], and they present the possible ways of the CE's implementation in municipal waste management in Poland. The examples of specific actions that can and should be implemented in the indicated areas are described and summarized in Table 3.

### *5.2. Perspective of Possible Application of Proposed Actions to the Polish Conditions*

The presented solutions for municipal waste management are complementary to the actions proposed by the Polish government in the CE Roadmap document, officially adopted in 2019. They are grouped in the following six actions, that can be taken by residents and governments in Poland in order to speed up the process towards CE implementation:

#### *5.2.1. Regenerate*

Regenerate is the first action in the proposed CE model framework. It includes actions aimed at transition to renewable materials and energy sources. The municipal waste can be treated as a source of energy, heat, or process steam recovery when it is directed to the installations for the thermal transformation of waste. Waste incineration must take place with all precautionary measures taken to prevent the generation of harmful emissions and the risk to health and life [66]. It should be underlined that, according to the European hierarchy, waste incineration with energy recovery is the latest option, just before the safe disposal. There are several waste-to-energy plants for municipal waste, including 1618 plants worldwide: 512 plants in Europe, 822 plants in Japan, 88 in the United States, and 166 in China (data from 2016) [67]. The waste-to-energy facilities can lead to an environmental load (as in France) or a saving (Germany and Denmark), mainly depending on the composition of the energy being substituted [68]. In Poland, there are many installations for municipal waste incineration; mainly, they were built in big cities with the support of the EU funds. These plants (which include the energy, heat, or process steam recovery) are currently operating (such as in Cracow [69]), and can be recommended in the areas of urban agglomeration where there is no place for installations for biological treatment of municipal waste. However, only mixed waste should be sent to combustion processes, because according to the concept of the CE, reuse should be the first option, then remanufacturing, and then recovery of raw materials from waste [2]. In Poland, the municipal waste stream should be sent to incineration after analyzing and separating its fractions for recycling, striving to use the energy potential of the fraction resulting from the operation of the installation for the mechanical–biological reactor (MBR) in installations with appropriate permits, to the extent that there is no threat to the established levels of preparation for reuse and recycling [48].

**Table 3.** Recommended CE actions in municipal waste management based on the ReSOLVE (Regenerate, Share, Optimize, Loop, Virtualize, and Exchange) framework.

No.	CE Area	Description	Examples
1	Regenerate	Energy, heat, or process steam recovery	Installations for the thermal transformation of municipal waste with energy recovery
		Reclaiming, retaining, and restoration of health of ecosystems	Landfill remediation
		returning recovered biological resources to the biosphere	Use of selected municipal waste fractions (e.g., from urban greenery) for fertilizing purposes
2	Share	Sharing the products with co-users	Cohousing—sharing of joint areas in flats or houses Clothes sharing, e.g., leasing or sharing of clothes, such as T-shirts, jeans, etc.
		Reuse of products by keeping the product loop speed low and maximization of the utilization of products	Donation for free or exchange for another product/service (clothes swap, toy swap) sale/resale of used goods and second-hand products
3	Optimize	Increasing product/technology performance and efficiency	Implementation of the most optimal solutions possible in the waste recovery and disposal processes
		Removal of waste from production processes	Comprehensive management of all waste streams
4	Loop	Keeping the components and materials closed	Creation of reuse points Repair points Creating food banks Eco-design
		Remanufacturing products or components, and, as a last resort, recycling materials	Repair points Eco-design
		Recycling and recovery of raw materials from waste streams	Increasing the efficiency of selective collection at source, including municipal biodegradable waste, in order for easy application of recycling/recovery technologies
5	Virtualize	Buying and using the utility virtually	Introducing virtual solutions in everyday life to reduce the amount of generated waste (such as newspapers, books, alarm clocks, music, online shopping, etc.)
6	Exchange	Replacing old materials with new advanced materials	Replacement of household appliances and items (such as refrigerators, dishwashers, freezers) by items with a higher energy class

Regenerate refers also to the reclaiming, retaining, and restoration of the health of ecosystems. In this case, the municipal landfills' remediation is recommended. Due to the need to adapt municipal waste landfills in Poland to technical and organizational requirements arising from legal provisions, the number of active landfills has been systematically falling for several years [58]. In the process of closing a landfill or part of one, reclamation works are carried out in a way that protects the landfill from its harmful effects on surface and underground waters and air, integrating the landfill area with the surrounding environment and enabling observation of the impact of the landfill on the environment. The main goal of municipal landfill remediation is to restore the natural value of the areas after closing and reclamation of these landfills. An example is the reclamation of 22 landfills in the Kujawsko-Pomorskie Voivodeship. The actions taken resulted in the fact that the areas covered by the scope of the project were made available in the form of educational paths for local communities after its completion. Path infrastructure has mainly enabled educational activities among children and adolescents, contributing to widespread awareness among local communities in the fields of ecology, environmental protection, and, in particular, rational waste management [70].

An important part of the Regenerate action is the idea of returning recovered biological resources to the environment. It refers to returning recovered biological resources to the biosphere, and can be done by the usage of selected municipal waste fractions (e.g., from urban greenery) for fertilizing purposes [71]. Here, biological methods of waste utilization can be used as composting and biogas production [72]. Both of these methods are carried out in a way that allows the control and enhancement of natural biological processes. Therefore, they can only act on biodegradable organic materials. Only mechanically separated organic waste from a mixed municipal waste or source-sorted biodegradable materials, which provide a cleaner organic stream, can be treated in the biological processes. For example, food and green wastes are suitable feedstock materials for these methods. Other biodegradable materials, such as card, paper, or wood can also be treated. These solutions can be realized by specialist companies, but also by the residents themselves (e.g., composting bins in the garden) [73]. The biological methods of waste management are strongly recommended in the first place in the CE (just after waste prevention, reuse, and remanufacturing).

### 5.2.2. Share

Sharing with co-users is a way to maximize the use of a product or service. This is one of the activities that helps minimize the amount of municipal waste generated by extending the life of specific goods. It can be clothes sharing, such as jeans and T-shirt leasing programs. Currently, the best-known brand in this area is the Dutch brand Mud Jeans, which introduced this program in 2013, which offers leasing a pair of jeans to the customers for one year for a monthly fee. After this period of time, jeans can be kept or traded in for a new pair. The used jeans then go back into the lease program or are recycled [74]. There are also some other clothes sharing programs, such as for T-shirts. In order to minimize the amount of goods that are not used all the time, cohousing can also be indicated. It is a combination of completely independent flats with a common space used by all residents (e.g., kitchen, laundry). This applies to, for example, devices that have a limited lifetime, and their functionalities should be maximized in that time, e.g., washing machine, fridge.

Sharing is also the reuse of products as long as they are technically functional and approved for use (e.g., second-hand principle) and extending the lives of products through maintenance, repair, and design methods that increase their durability. The products that are no longer needed by residents would normally be removed as municipal waste. In line with the CE idea is their sale or resale. There are many platforms that offer the opportunity to sell used goods free of charge. Moreover, there is also a possibility to exchange or give away things that are not needed. In Poland, there are more and more food sharing restaurants where people can bring food they do not need anymore and take something else instead. Special dedicated platforms were also invented in order to exchange goods, such as toy swaps where children exchange toys they no longer use. This helps the reduction of

consumption of newly produced physical products. The sharing economy has many common aspects with the Loop action, which is presented below.

In the model of the sharing economy, sustainability might be an important factor for those residents for whom ecological consumption is important [75]. This phenomenon of sharing economy has grown in the last few years, and it is expected to expand and grow steadily in the coming years [76].

### 5.2.3. Optimize

Optimization activities focus primarily on increasing product/technology performance and efficiency, as well as removing waste in the production process and supply chain. Here, an important recommendation is eco-design of the products [77]; for example, energy-related items [78]. The eco-design of products is a key factor in the European strategy for Integrated Product Policy. As a preventative approach, eco-design can be used to optimize the environmental performance of products while maintaining their functional qualities; it provides genuine new opportunities for manufacturers, consumers, and society as a whole [33]. In the area of municipal waste management, optimization also refers to technologies for the treatment of municipal waste. The installation operators should implement the most optimal solutions possible in the waste recovery and disposal processes. Optimization can be adopted to increase the efficiency of processing mixed waste in the mechanical part of the MBR so that as much waste as possible is generated for recycling and recovery, and as little as possible for landfilling. It could also be applied to increasing the efficiency of mixed waste processing in the biological part of the MBR so that the processed waste meets the requirements for storage [48].

Optimization also includes the removal of waste from production processes, which is in line with the assumptions of the “zero waste program for Europe” [1]. This means that all waste streams that are generated by residents should be treated and recovered (if applicable).

### 5.2.4. Loop

The Loop action is related to keeping the components and materials closed. This means product reuse; in the case of municipal waste other than food waste and biodegradable waste, this means creation of reuse points enabling the exchange of used items, such as at the municipal selective waste collection center in Poland, among others. Such points should provide the possibility of leaving functional and unnecessary for example, home appliances, as well as the possibility to download other useful things. This can be the creation of repair points for things and products that owners would like to continue using or transfer after repair, and the organization of exchanges of various things, including, in particular, household appliances, clothes, and footwear. Closing the loop can be realized on a local level by creating food banks that collect and distribute food with a short time remaining until its expiry date for people in need, or using food waste that is not suitable for humans for other purposes. An important element is eco-design, which is the systematic consideration of environmental aspects when designing a product, as well as design that extends the life of the product and allows the reuse of elements, and also allows for the easy remanufacture of the products [48].

Closing the loops in the municipal waste management means the recycling and recovery of raw materials from waste streams. The increasing the efficiency of selective collection at the source, including municipal biodegradable waste, could help in the further application of selected recycling/recovery technology for the specific waste stream. For renewable materials, this means anaerobic digestion and extraction of bio-chemicals from organic waste [23].

### 5.2.5. Virtualize

Virtualize is a model of operation that assumes the provision of specific usability virtually instead of materially. It can help reduce the amount of municipal waste generated by the residents. The consumers should replace the tangible items with intangible items that have the same utility values. An example of this is the replacement of paper newspapers and books with online magazines and e-books, which leads to less paper being used and less paper waste. Another example is the

replacement of traditional alarm clocks with, e.g., cell phones that also have wake-up calls. Music can be bought virtually instead of on normal CDs and tapes [23].

#### 5.2.6. Exchange

The Exchange model assumes the replacement of old materials with new advanced materials, using modern technologies, and selecting modern products and services. It refers to replacement of household appliances and items that are, e.g., economically inefficient. Residents should replace old household appliances and items, such as refrigerators, dishwashers, and freezers, with items with a higher so-called energy class. This is calculated on the basis of annual power consumption and the ratio of standard values corresponding to the most common models of a given device. It is specified in kilowatt hours. The need to set this parameter is determined by EU directives. Due to full transparency, consumers can compare models from different brands and consciously decide to buy more or less energy-saving equipment. The energy class is assigned to a scale from A to D or G, where the first of the letters is the most economical in power consumption. The corresponding colors of the stripes also accompany this marking. The energy label has green, yellow, and red in various shades. Due to the dynamic development of the household appliances industry, in December 2010, the classification was updated by introducing three new markings for the most effective devices: A+, A++, and A+++. More and more consumers pay attention to the energy efficiency class because of concern for the environment. Lower power consumption will definitely be kinder to it. The overwhelming majority of the population, however, is analyzing this parameter because of the potential savings on bills.

The recommended actions that have been grouped into areas of particular significance (indicated in the ReSOLVE framework) present model solutions that can be implemented in various municipal waste management systems, not only in Poland. It should be pointed that the indicated propositions of actions are examples of good practices; anyway, there is no single CE model that can be easily adopted for each country or region (e.g., big cities or small communities) due to social, environmental, financial, and political differences [61]. The successful introduction of solutions that are in line with the CE model requires the involvement of all stakeholders in a given region or country. This work focuses on the responsibility of local authorities and the residents themselves. It should also be emphasized that, despite the global campaign for the prevention of waste generation as well as for the primary segregation of waste, differences in the management of municipal waste are still clear. Further promotion of circular attitudes is necessary.

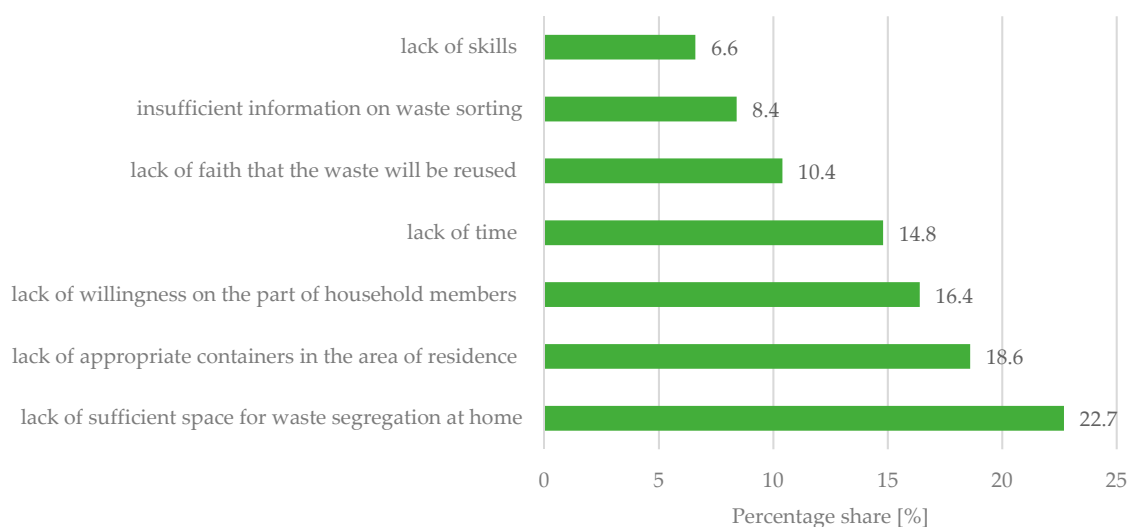
## 6. Discussion

The activities of the European Commission seek a reduction in waste production and the recovery of valuable raw materials from waste as much as possible, which is in line with the idea of the circular economy. The action proposed in the CE model framework (Table 3) allows for faster implementation of CE principles in waste management in various European countries. It should be underlined that the introduction of recommendations regarding the implementation of the CE [4] and increasingly restrictive legal provisions on waste aim to ensure proper waste management in order to reduce its harmful effects on the health and lives of both current and future generations (Agenda 2030) [20] and the environment. In the field of municipal waste management, the EU aims to reduce the amount of waste deposited in landfills and to increase the share of recycling as the recommended waste management method [5]. Despite the overall positive trend for the EU in terms of both reducing the amount of municipal waste disposed of and increasing the level of recycling of this waste (from 25 million Mg, i.e., 52 kg per capita in 1995, to 74 million Mg, i.e., 144 kg per capita in 2017), significant disparities between individual European countries are noticeable [37]. In highly developed countries, such as Germany, Austria, or Denmark [79], the importance of recycling or energy recovery from waste and the use of green production technologies can already be seen. Poland is one of the countries in which landfilling is still one of the basic methods of municipal waste treatment (42% in 2017); therefore, Poland belongs to those EU countries in which municipal waste management should be



improved. This may be implemented due to the introduction of the amended Waste Act, which is to help reduce the impact of resource use and improve waste management efficiency. In accordance with the recommendations contained in the National Waste Management Plan, the goals to be achieved by 2030 clearly indicate the need to significantly reduce the amount of landfilled waste and limit landfilling only to previously processed waste. Consequently, it is not recommended to create further landfills for the storage of municipal waste and derived from the municipal waste stream, but to increase the expenditure on other forms of waste management, mainly through recovery. In accordance with Polish legislation, however, detailed analysis in this area belongs to the marshals of voivodships [48]. There is a strong need to create a more effective municipal waste management system in Poland, which is also inscribed in the National Development Strategy 2020 [80], which assumes that the overarching goal of waste policies should be to prevent waste generation when solving the problem of waste at the source and the maximum possible recovery of raw materials and/or energy. The introduction and implementation of the "3U" principle (avoid waste generation, reuse, utilize; in Polish, 3U—unikaj powstawania odpadów, użyj ponownie, utylizuj) and management of circulation in line with the concept of the CE are indicated. This can be done through activities such as introducing a system of selective collection of municipal waste throughout the country, construction of installations for recovery (including recycling) and disposal of municipal waste, closing and reclamation of municipal waste landfills that do not meet standards defined by law or are burdensome for the environment, liquidation of illegal dumps, and reducing the amount of municipal waste going to landfills by, among other things, subjecting it to recovery. The National Development Strategy 2020 (SKR) also assumes the need for legislative changes, allowing for easier implementation of priority investments in the field of modern waste management [80].

Poland has recently undertaken many activities in the area of implementing CE assumptions in municipal waste management, and the importance of this sector is clearly emphasized in the Polish CE Roadmap, which was approved by resolution of the Council of Ministers in September 2019. In the Polish CE Roadmap, a special section is dedicated to municipal waste in the area of the sustainable consumption. The Polish Roadmap also presents proposals for actions of the Polish government in the field of CE implementation in the sector of municipal waste management [49]. Compared to other waste-related documents, the CE Roadmap clearly underlines that conversion to a truly circular economy requires an introduction of additional measures not only in the area of municipal waste management, but also in the field of sustainable production and consumption, putting emphasis on the entire life cycle of products in a way that saves resources and closes circulation. In the process of transformation to the CE, consumers themselves have a very large impact on municipal waste management, and without their timely commitment, the circular economy model in Poland and in other countries may simply not work. The cyclical research on ecological awareness and behavior in Poland is monitored as part of the multi-annual research program of the Ministry of the Environment. Based on the one-meter waste management survey conducted in 2017, it was shown that 70.4% of Poles declare the segregation of municipal waste, including 53.2% regular and 17.2% sporadic. In turn, 26.6% of residents indicate that waste is thrown into one common bin. There are also some barriers to selective waste collection, such as lack of sufficient space for waste segregation at home, lack of appropriate containers in the area of residence, lack of willingness on the part of household members, lack of time, lack of faith that the waste will be reused, insufficient information on waste sorting, or lack of skills [81]. These are summarized in Figure 4.



**Figure 4.** Main barriers to selective municipal waste collection in Poland (Source: Own, based on [81]).

According to the waste management hierarchy, waste prevention should be the first priority, and landfill disposal is the last option [82]. Thus, almost half of the Poles surveyed declared they were familiar with the concept of measures to minimize the amount of municipal waste generated (48%), while 34.2% indicated the lack of such steps [81]. According to the Stena Recycling study, in 2017, only 29% of Polish residents met with the term “circular economy” [83]. Despite the fact that Poles’ knowledge about CE was small, they were taking actions in a circular direction, such as the use of reusable bags (69%) and the avoidance of waste generation by purchasing only the products needed (64%). In addition, in accordance with the CE framework proposed by the Ellen MacArthur Foundation (ReSOLVE framework—Regenerate, Share, Optimize, Loop, Virtualize, Exchange) [23], measures should be taken to increase the efficiency of physical resources’ use and extend their lives [64]. According to this idea, more than half of Poles (54.4%) declare the repair of broken devices and the reuse of waste through their commissioning or sale [81]. Unfortunately, beliefs about the real impact of consumers on the environment in which they live and, as a result, on the quality of life of present and future generations are still unsatisfactory. Price is still a decisive criterion when making consumer choices. Meanwhile, consumer choices are one of the most important environmental impact instruments [84]. The presented results indicate the need for further education of the society in terms of reducing waste generation, as well as its reuse and selective collection [81]. The business sector should also be made aware of the main targets for waste management in the CE model [85,86]. One of the examples of a successful Polish campaign in this area was a special supplement to “Rzeczpospolita”—a business-oriented daily newspaper, which was fully dedicated to the CE [19]. Thanks to this initiative, many entrepreneurs have learned how important waste management is in the context of the transformation towards CE.

Municipal waste management in Poland is facing a number of challenges in the aspect of implementing the circular economy, primarily in achieving recycling values imposed by the European Commission—a minimum of 55% by 2025—as well as greater consumer involvement and awareness-raising in the field of circular economy. Undoubtedly, the improvement of efficiency in the field of municipal waste management is one of the key actions in the implementation of CE assumptions. Moreover, the transition to the CE model is an indispensable element of implementing the initiative for resource efficiency provided for under the Europe 2020 strategy for smart, sustainable, and inclusive growth [87]; therefore, undertaking activities that are indicated as recommended is of particular importance. The Commission promotes activities in the field of the circular economy by underlining that the implementation of the CE systems improves resource efficiency and brings significant economic benefits to EU member states, including Poland [88]. The further activities in the field of CE implementation in the Polish municipal waste management system should be

carried out both by the government and by the residents themselves, thanks to education in this area. This can be supported by the many national and international funds, such as, for example, Horizon Europe [89], which is an ambitious 100 billion EUR research and innovation program to succeed Horizon 2020 [90]. Both of these programs support the implementation of the CE solutions in many sectors, including municipal waste management on local, regional, national, and international levels. Moreover, the European Investment Bank [91,92] in Poland has already had many achievements in the waste management sector, such as numerous projects to improve the environment and quality of life of Polish residents. Further investments in this area are possible in the coming years.

## 7. Summary and Conclusions

Municipal waste management is currently an important area of CE implementation in European countries. The EC recommended that the member countries develop planning documents for the implementation of the CE in various areas of activity, with particular emphasis on municipal waste because this issue occurs in all countries. In Poland, the CE roadmap was developed by CE Working Group and approved by the government in 2019. A special area of the Polish CE roadmap is dedicated to municipal waste management, in which some specific recommended actions are indicated, such as changes in legislation, improvement in the waste management system, prevention of food waste, and education of residents about the importance of CE implementation in everyday life.

There are some small achievements in the CE implementation in Polish municipal waste management. The municipal waste generation in Poland was increasing in previous years, to 329 kg per capita in 2018; however, it is still one of the lowest in the EU. Municipal waste recycling in Poland was also increasing in last years, from 26.5% in 2014 to 34.3% in 2018; however, this value is unsatisfactory because it is below the European average. Further activities in the scope of development of municipal waste treatment infrastructure should be implemented, as well as encouraging all citizens to take actions to support the government's activities in the field of implementation of the CE in the country. The current paper presents the inventory of recommended actions that should be taken by governments and the residents themselves, such as:

- Regenerate—landfill remediation and use of selected municipal waste fractions for economic purposes;
- Share—sharing the products with co-users, such as cohousing, clothes sharing, and reuse of products;
- Optimize—most optimal solutions in the waste recovery and disposal processes and comprehensive management of all waste streams;
- Loop—remanufacturing products or components and recycling/recovery of raw materials;
- Virtualize—virtual solutions in everyday life to reduce the amount of generated waste;
- Exchange—replacement of household appliances with items with a higher energy class.

The indicated solution can be also adopted in other municipal waste management systems as the recommended direction in the process of the transformation towards CE in Europe.

**Supplementary Materials:** The following are available online at <http://www.mdpi.com/2071-1050/12/11/4561/s1>, Table S1: Characteristics of the ReSOLVE model.

**Author Contributions:** All authors contributed in the development of the current paper. The concept and methodology were prepared by M.S., while the detailed literature review, discussion, and development of the conceptual framework were done by M.S., J.D., A.C.-K., and D.S.; writing—original draft preparation was done by M.S.; writing—review and editing was done by A.C.-K. and D.S.; supervision was done by M.S. and J.D. All authors have read and agreed to the published version of the manuscript.

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